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Int J Adv Manuf Technol
DOI 10.1007/s00170-017-0599-0

ORIGINAL ARTICLE

A study on the different finite element approaches for laser cutting of aluminum alloy sheet

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Received: 9 January 2017 / Accepted: 31 May 2017

Abstract The effectiveness of finite element simulation techniques for laser cutting of 1.2-mm-thick aluminium sheets has been studied. Lagrangian and Arbitrary Lagrangian-Eulerian techniques were used to model and simulate laser cutting process. The reliability of finite element results were evaluated by general energy balance analysis and experimental results. Temperature and stress distribution along with heat-affected zone were predicted during the laser-induced process in line with experimental conditions under ABAQUS finite element code. Heat transfer analysis relying on thermal loading was employed to reach the best efficiency. By using field-emission scanning electron microscope, morphological, structural, and elemental changes in the cutting sections were analyzed along with the X-ray diffraction technique. Obtained stress and heat-affected zone are highly dependent on the element type as well as numerical method. Both numerical method, ALE and Lagrangian, are compared to each other in terms of power absorption, cut surface morphology, and cutting efficiency. The results show that ALE method is in good agreement with experimental data.

Keywords Laser cutting · Aluminum sheets · Finite element method · General energy balance · Thermal stress

1 Introduction

In today's competitive industrial environment, the vast majority of manufacturing firms are utilizing technological methods to enhance workplace productivity. In between, the laser cutting has turned to be one of the effective methods for cutting sheet metals due to its flexibility and time consuming. Moreover, unlike conventional cutting methods, laser cutting offers significant advantages in terms of productivity where it could be performed by inducing the high intensity laser beam over small region of material [1, 2]. Considerable research studies indicate that great variety of existing mass production in automotive, aerospace, and computer industry relies on aluminum sheets [3].

The laser cutting as a powerful method could localize temperature by inducing temperature gradient along the cutting path. Some studies have conducted the effects of temperature gradient and thermal stress in laser cutting process. Experimental results in these research indicate that power density, cutting speed, and laser pulse, as significant control factors, have direct effects on microstructural characteristics, grain morphology, kerf dimension, and surface finishing [4–6].

Stournaras et al. [7] were carried out a statistical study on the effect of significant parameters on laser cutting process . Also, Wang et al. [8] have found that, in laser cutting process, the quality of surface in cutting section is considerably affected by the size of spherical particle under various melting ratio.

Several theoretical studies have evaluated the effect of temperature and stress in laser cutting in order to enhance

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Published online: 13 June 2017